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[54]发明名称 重量补偿的方法的装置

[57]摘要

一种用于动态平衡一个失衡的旋转部件的平衡装置。当该装置被装在一个轴或其他可转动部件上并旋转时，安装在第一槽或沟道内的第一系列相同尺寸和重量的重物可自由运动。具有相同尺寸和重量的第二系列重物被类似地装入位于第一槽内侧的第二槽内自由运动。第一系列重物的尺寸和重量与第二系列重物不同。

图１５Ａ是装有平衡装置的洗衣机槽的外部示意图；

图１５Ｂ是沿图１５Ａ中１５Ｂ－１５Ｂ方向的示意图；

图１５Ｃ是沿图１５Ａ的１５Ｃ－１５Ｃ方向的示意图；

图１６是机动车后端的驱动轴和差动器的示意图；以及

图１７是一典型的曲轴，它接至压缩机活塞，该压缩机装有本发明的平衡装置。

现参见附图，在图1中用10表示按照本发明的平衡装置的总体。它包括第一组环形槽11，12，13，14及15，可以理解，相互对置的槽11和15通常是相同的。而对置的槽12和14通常也是相同的。

多个通常为圆形球状的重物21，22，23，24，25分别装在槽11，12，13，14，15中。在各个槽中的多个重物的尺寸和重量相同；也就是说，在槽11中的重物21的尺寸和重量都相同，在槽12中的重物22的尺寸和重量也都相同，等等。然而，重要的是在至少二个槽中的重物具有不同的尺寸和重量；也就是说，在槽13中的重物23最好是大于且重于槽14中的重物24。

球状物21，22，23，24，25可绕平衡装置10的圆周分别在槽11，12，13，14，15中自由运动。给平衡装置10加上硅润滑剂以减少球在平衡装置运行时由球状物产生的噪声，这在下面将予以说明。

球状物21，22，23，24，25由淬硬材料，例如硬质合金制成。同样，沟道或槽11，12，13，14，15也是淬硬的。硬化是合乎需要的，以阻碍或防止球状物或沟道产生磨损，这种磨损势必降低球状物在沟道或槽中自由运动的能力且由此阻碍了球状物平衡运动有效性。

在运行中，可以用一个在平衡装置10与转轴32之间的键31把装

于平衡状态并旋转时突然遇到失衡的情况下，可以想像，在给系统造成损害的后果之前，重物21不能足够快地消除失衡情况。

用来改进"快速性"的装置可以采用多种形式，系统响应该装置去消除失衡状态。例如设想把一种实物加到槽11上，从而在重物21上施加作用力，该作用力使重物21从静止位置运动到部件10的"最上部"位置，并且从由部件10的轴线26延伸出的半径25的一侧运动到相反的另一侧。作为替代，也可以使用机械或电气的装置。

参见图11，设想槽11内的重物21最初的运动是由加到槽11的实物所引起的，该实物最初向重物施加一点力从而使重物21运动。例如，这种实物可以是一种粘稠的流体，使重物产生旋转运动，例如一种油脂。本文中不打算对所有的这类实物加以详细说明，但是它可以包括能使重物21开始运动的任何实物。甚至沙土也可设想被用做这种实物，当然，不宜使用沙土，因为沙土不够纯净并且最终将与槽11内的重物21粘合在一起，从而影响正常操作中对重物运动的快速性要求。

还可以设想从平衡装置10外部启动重物的运动。例如当重物由磁性材料制成时，可以由一个外部附件(未示出)向重物施加适当的磁场，在出现失衡状态时使重物立即能相应地运动。这样做将会缩短重物21的转动时间，以消除不平衡状态，且由此减少了造成失衡装置损害的可能性。

参见图12，其中的平衡装置总体由100表示。在平衡装置100中添加一种液体101，并且其液面高于可运动的球状重物103。在槽110中形成一V形槽104，使球体103在槽中容易运动。V形槽104有多个从槽104延伸到储液容器(未示出)的通道111。

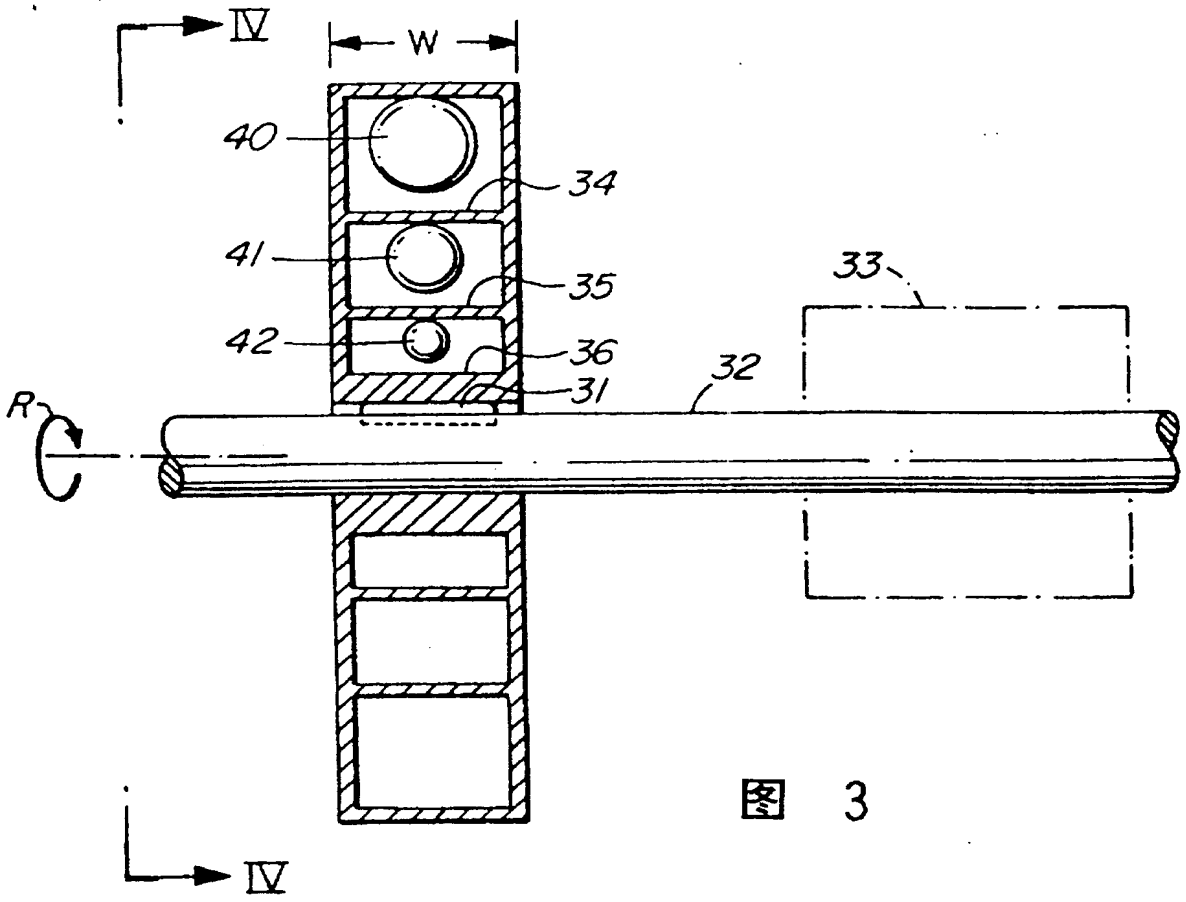

图 3

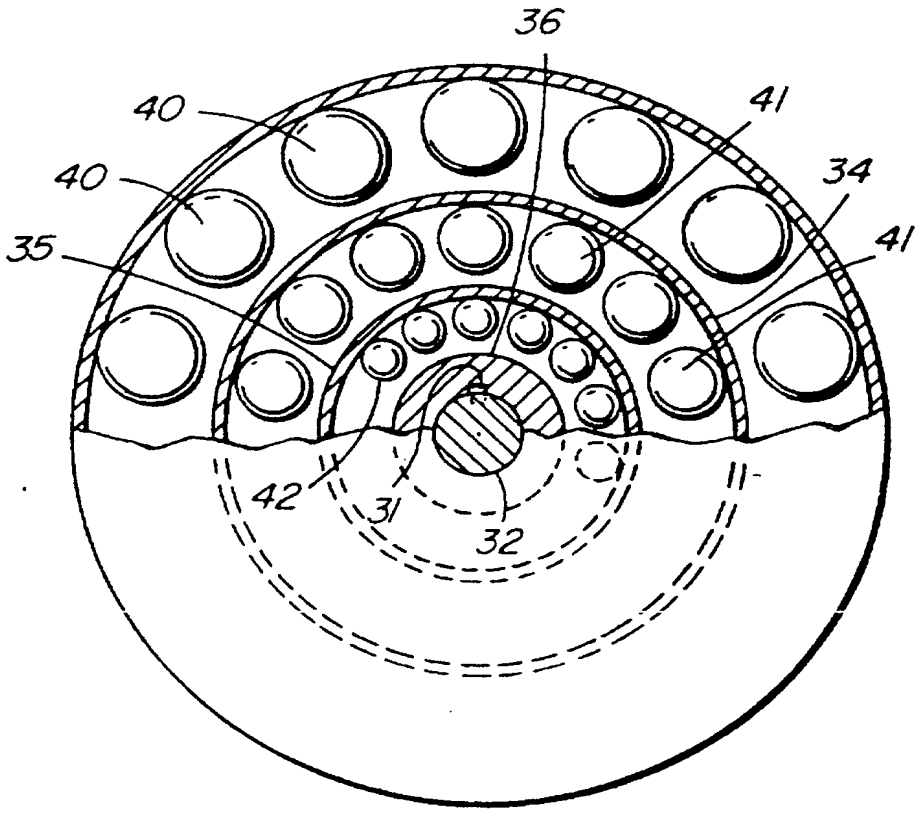

图 4

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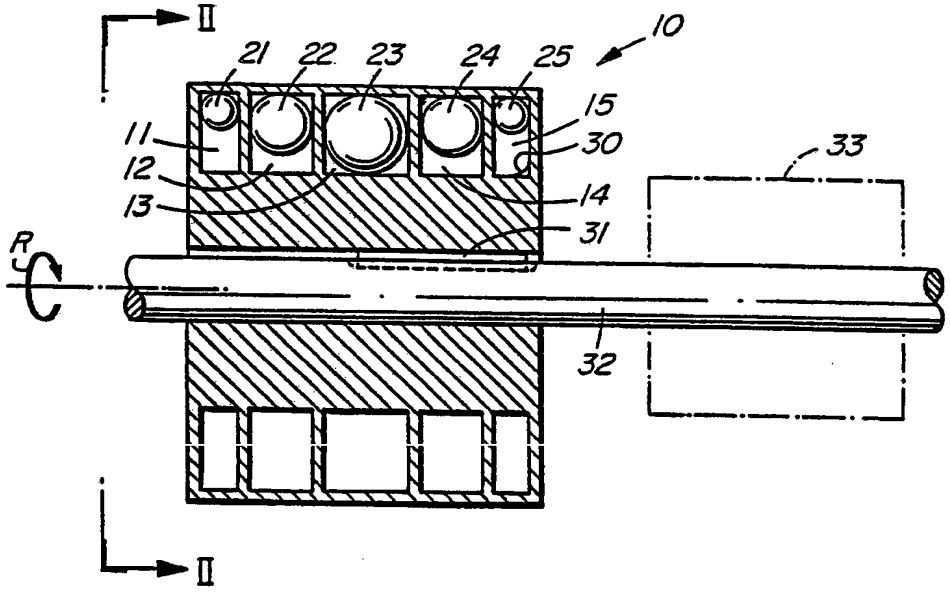

(57) Abstract

A counterbalancing apparatus for dynamically balancing an out-of-balance rotating member. A first series of weights having identical size and weight are mounted to freely move within a first groove or race when the apparatus is rotating after being mounted to a shaft or other rotatable member. A second series of weights having identical size and weight are similarly mounted to freely move within a second groove or race located inside of the first groove. The first series of weights is different in size and weight from the second series of weights.

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AN UNBALANCE COMPENSATING METHOD AND APPARATUS.

INTRODUCTION

This invention relates to a balancing method and apparatus and, more particularly, to a balancing method and apparatus used for dynamically balancing an out of balance condition in a rotating body.

BACKGROUND OF THE INVENTION

Many different apparatuses for balancing an out of balance condition in a rotating body are known. Such apparatuses generally include a counterweight having a weight of a predetermined value which is located at a predetermined position from the axis of rotation to oppose an imbalance in the rotating body. The magnitude of the imbalance is generally known and, accordingly, the necessary weight and position of the counterweight can be calculated so that the weight is positioned where it will act to counter the known imbalance. These apparatuses function satisfactorily for most purposes under which they are employed but are not precise or useful enough for other applications.

Under dynamic conditions; that is, when a body is rotating about an axis and an imbalance in the rotating body develops because of external conditions or otherwise, the prior art is much less satisfactorily developed. For example, in a drill bit or in a drillstring, vibration induced forces during operation can create severe unbalances. One technique used to counteract such imbalances is disclosed in U.S. Patent 4,905,776 (Beynet et al). Beynet et al teach a vibration dampening assembly with a plurality of annular grooves or races located about the periphery of the assembly and extending axially

therealong. A plurality of balls or rollers are located in each of the races. Such balls or rollers are free to move along the races and thereby counteract the imbalance forces.

A further similar structure is disclosed in U.S. Patent 4,674,356 (Kilgore). Kilgore teaches a plurality of balls freely movable in a race formed in an outer circumferential surface of the body which balls are used to counterbalance an imbalance in the rotating member.

There are, however, disadvantages in such prior art. Although the Beynet et al reference is satisfactory to remove large imbalances from the rotating body, it is difficult to utilise the teachings of Beynet et al where the length of the balancing apparatus is necessarily restricted which is often the case. Likewise, while the teachings of Beynet et al are satisfactory to generally remove large imbalances from the drillstring, there is no provision therein for removing all or most of the remaining imbalance thereafter, particularly the imbalance that may remain when the balls in the races of Beynet et al are located at their optimum positions in the races to counteract the imbalance.

This latter problem is also inherent in the above mentioned Kilgore reference. Kilgore teaches two counterbalance structures, one located at each end of a shaft, to offset the imbalance in the shaft or the unbalanced forces in the rotating structure which is movable with the shaft. If the balls are not located at their optimum positions, the imbalance in the shaft will not be removed.

SUMMARY OF THE INVENTION

According to one aspect of the invention, there is provided a counterbalancing structural member rotatable about an axis, said member comprising first and second annular grooves concentric to said axis and extending around said axis, a first plurality of weights freely movable in said first annular groove, a second plurality of weights freely movable in said second annular groove, said first plurality of weights in said first annular groove being substantially the same weight and size, said second plurality of weights in said second annular groove being substantially the same weight and size, said weight and size of said second plurality of weights being different from said weight and size of said first plurality of weights.

According to a further aspect of the invention, there is provided a method of dynamically balancing a rotating member comprising the steps of positioning a first plurality of weights having the same size and weight in a first annular groove in a rotating structure, positioning a second plurality of weights having the same size and weight and different from the size and weight of said first plurality of weights in a second annular groove in said rotating structure and rotating said structure while allowing free movement of said first and second plurality of weights in said first and second annular grooves.

According to yet a further aspect of the invention, there is provided a method to counter an imbalance in a rotary member comprising the steps of positioning a counterbalance structure on the axis of said rotary member, positioning a first plurality of weights having the same weight and size in a first annular groove

located coaxial with said axis and extending about the circumference of said structure, and allowing each of said first plurality of weights to freely move within said first annular groove, positioning a second plurality of weights having the same weight and size in a second annular groove located coaxial with said axis and inside said first annular groove and allowing each of said second plurality of weights to freely move within said second annular groove, said second plurality of weights having a different weight and size from said first plurality of weights.

According to yet a further aspect of the invention, there is provided a method to counter an imbalance in a rotary member comprising the steps of positioning a first half of a structural member having first and second annular grooves with freely movable weights located in each of said annular grooves on a rotary member, positioning a second half of a structural member having third and fourth annular grooves symmetrical with said first and second annular grooves of said first half of said structural member on said rotary member, connecting said first and second halves, rotating said rotary member and allowing said freely movable weights to position themselves within said grooves so as to remove substantially all of said imbalance.

According to yet a further aspect of the invention, there is provided a counterbalancing apparatus comprising a shaft having an outer diameter, at least two grooves formed in said shaft, said grooves being coaxial with the axis of said shaft and formed one inside the other, the outside one of said grooves being inside the outer diameter of said shaft, freely movable weights positioned in each of said grooves and means to retain said weights in said grooves.

According to yet a further aspect of the invention, there is provided a counterbalancing structural member rotatable about an axis, at least one groove in said structural member being concentric with said axis, at least one weight movable in said groove, and means to retain said weight stationary relative to said groove until said weight moves from one side of the vertical radial extending upwardly from said axis to the other side when said structural member is rotated about said axis.

According to yet a further aspect of the invention, there is provided a washing machine having a water retaining cylinder rotatable about an axis, at least one cylindrical balancing device having an axis and being mounted concentric to said axis, said balancing device having at least two passageways, movable weights within each of said passageways, said movable weights in said first passageway being all substantially the same size, said movable weights in said second passageway being all substantially the same size, the movable weights in said second passageway being a different size from the movable weights in said first passageway.

According to yet a further aspect of the invention, there is provided a washing machine having a water retaining cylinder being rotatable about an axis, at least one cylindrical balancing device operably connected to said cylinder and having an axis, said balancing device being mounted concentric to said axis, said balancing device including at least one passageway to hold movable weights, said weights being rotatable with said balancing device and being movable relative to said passageway, all of said weights in said passageway being substantially the same size.

According to yet a further aspect of the invention, there is provided a balancing device being operably connected to a rotating member and being concentric with the axis of said rotating member, said balancing device having at least one passageway extending circumferentially about the axis of said balancing device, a plurality of weights within said passageway and being movable relative to said passageway, means to maintain said weights substantially stationary relative to said passageway until a predetermined rotational speed of said balancing device is reached.

According to yet a further aspect of the invention, there is provided an axle for a vehicle or the like, said axle being rotatable about an axis, a balancing device being operably connected to said axle and having a passageway extending about the axis of said axle, a plurality of weights in said passageway and being movable within said passageway, all of said weights in said passageway being substantially the same size.

According to yet a further aspect of the invention, there is provided a compressor having at least one piston operably connected to a rotatable crankshaft, a balancing device being operably connected to said crankshaft and having a circumferential passageway extending about the axis of said crankshaft, said passageway having a plurality of weights movable relative to said passageway, each of said plurality of weights being substantially the same size.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

Specific embodiments of the invention will now be described, by way of example only, with the use of drawings in which:

Figure 1 is a side sectional diagrammatic view of a first embodiment of the counterbalancing apparatus according to the invention;

Figure 2 is an end view taken along II-II of Figure 1;

Figure 3 is a side sectional diagrammatic view of a second embodiment of the counterbalancing apparatus according to the invention;

Figure 4 is an end view taken along IV-IV of Figure 3;

Figure 5 is side sectional view of yet a further embodiment of the counterbalancing apparatus according to the invention;

Figure 6 is a side sectional diagrammatic view of yet a further embodiment of the counterbalancing apparatus according to the invention;

Figure 7 is a side sectional diagrammatic view of the apparatus of Figure 6 illustrated in its operating position;

Figures 8A and 8B are end views of a further embodiment of the invention mounted about a shaft and illustrating the counterbalancing apparatus in assembled and disassembled condition about the shaft, respectively;

Figure 9 is a diagrammatic side view of yet a further embodiment, the counterbalancing apparatus according to the invention being operably located within a shaft;

Figure 10 is a diagrammatic end view taken along X-X of Figure 9 illustrating a representative position of the movable weights during rotation of the shaft in which the apparatus is located; and

Figure 11 is a view of the counterbalancing apparatus according to the invention illustrating the vertical radial from the axis of the apparatus.

Figure 12 is a diagrammatic cross-sectional view of a ball retaining apparatus according to a further embodiment of the invention;

Figure 13 is a diagrammatic cross-sectional view of a ball retaining pin apparatus according to a further embodiment of the invention;

Figure 14 is a cross-sectional view of two versions of balancing devices according to the invention, either of which might be used with an ordinary ball bearings;

Figure 15A is a diagrammatic view of the outside of the tub of a washing machine with balancing devices mounted thereon;

Figure 15B is a diagrammatic view taken along 15B-15B of Figure 15A;

Figure 15C is a diagrammatic view taken along 15C-15C of Figure 15A;

Figure 16 is a diagrammatic view of the rear end drive axle and differential of a vehicle; and

Figure 17 is a view of a typical crankshaft which is connected to a piston of a compressor with balancing devices attached according to the invention.

DESCRIPTION OF SPECIFIC EMBODIMENT

Referring now to the drawings, a counterbalancing apparatus according to the invention is illustrated generally at 10 in Figure 1. It comprises a first set of annular grooves 11, 12, 13, 14 and 15, it being understood that oppositely located grooves 11, 15 are conveniently identical and that oppositely located grooves 12, 14 are also conveniently identical.

A plurality of weights 21, 22, 23, 24, 25, conveniently spherical in the form of balls, are mounted in the grooves 11, 12, 13, 14, 15, respectively. The plurality of weights in each of the grooves are all the same size and weight; that is, the weights 21 in groove 11 are all the same size and weight, the weights 22 in groove 12 are all the same size and weight and so on. It is important, however, that the weights in at least two of the grooves be different in size and weight; that is, the weights 23 in groove 13 are preferably larger and heavier than the weights 24 in groove 14.

The balls 21, 22, 23, 24, 25 are freely movable in their respective grooves 11, 12, 13, 14, 15 about the circumference of the counterbalancing apparatus 10. A silicon lubricant 30 is added to the counterbalancing apparatus 10 in order to reduce the friction between the balls and their respective races or grooves and to also reduce the noise made by the balls when the counterbalancing apparatus is in operation as will be described hereafter.

The balls 21, 22, 23, 24, 25 are manufactured from a hardened material such as carbide. Likewise, the races or grooves 11, 12, 13, 14, 15 are hardened. The hardening is desirable in order to retard or prevent the formation of "flats" on the balls or races which tend to reduce the ability of the balls to move freely within the grooves or races and thereby retard the effectiveness of the counterbalancing movement of the balls.

OPERATION

In operation, the counterbalancing apparatus 10 is installed on shaft 32 so as to fixedly rotate therewith such as by using a key 31 between the apparatus 10 and the shaft 32. The operation of an unbalanced member generally illustrated at 33, which creates an out of balance condition, is initiated and shaft 32 rotates with member 33 and counterbalancing apparatus 10 as illustrated.

As an out of balance condition originates within member 33, the balls 21, 22, 23, 24, 25 in each of the grooves 11, 12, 13, 14, 15 move and act to counterbalance the out of balance condition.

It is difficult to precisely state the principle by which the balls are known to move and while it is believed that empirical data will subsequently lead to formulae and better understanding to predict the optimal behaviour of the counterbalancing apparatus 10, the following explanation is given with the expectation that further information presently not known will amplify, modify or change such explanation.

It is believed that the larger balls 23 in groove 13 will remove the larger out of balance condition

in member 33. The somewhat smaller balls 22, 24 in grooves 12, 14 will act to remove the somewhat smaller out of balance condition in member 33. Finally, the smallest balls 21, 25 in grooves 11, 15 will act to remove the smallest out of balance condition in member 33. Thus, the entire out of balance condition in member 33 is removed by "fine tuning"; that is, by removing the imbalance under dynamic conditions with a plurality of different sized balls positioned in separate grooves which balls optimally remove different degrees of imbalance.

With reference to Figure 2 which illustrates the leftmost groove 11 of Figure 1 with the balls 21 in a representative and dynamic balanced position offsetting the unbalance in member 33, as viewed with a timing light adjusted for appropriate shaft r.p.m., it has been found that the optimum behaviour for the balls 21 occurs when they do not contact each other in the dynamically balanced position as is illustrated. It has been found that when many of the balls 21 come into contact with each other, the balancing phenomenum is not optimal and modification of the counterbalancing apparatus 10 may be necessary by way of structural or weight changes.

The embodiment of the invention illustrated in Figures 1 and 2 is conveniently used when there is a large potential imbalance problem in member 33 under dynamic operating conditions. If the potential imbalance problem in member 33 is small, the number of grooves and associated balls therein can be reduced to as few as two (2), with all of the balls in each respective groove being the same size and weight and the balls of the first groove being different in size and weight from the balls of the second groove, the former balls acting to remove the large imbalance and the latter balls acting to remove a smaller remaining imbalance.

Referring now to Figures 3 and 4, there is illustrated a further embodiment which is desirable when the width "W" as illustrated in Figure 3 is limited. In this embodiment, there are three grooves or races 34, 35, 36 with balls 40, 41, 42 mounted therein, respectively. The balls 40 in groove 34 are all the same size and weight. The balls 41 in groove 35 are likewise all the same size and weight and the balls 42 in groove 36 are likewise all the same size and weight. The balls 40 in groove 34, however, are larger and heavier than the balls 41 in groove 35 which, in turn, are larger and heavier than the balls 42 in groove 36. Under operating conditions and when an imbalance occurs in member 33 during rotation of shaft 32, the balls 40, 41, 42 will assume positions which counter the imbalance. A representative view of the positions of balls 40, 41, 42 illustrated in Figure 4 would be positions where the imbalance is removed optimally; that is, and as earlier described, the balls in each race or groove do not contact each other.

A further embodiment of the invention is illustrated in Figure 5. In this embodiment, wherein the width "W" is again of concern, a first plurality of cylindrical disc-like weights 50, 51, 52 are positioned to be freely movable in each of the grooves 43, 44, 45 which grooves 43, 44, 45 are formed by circumferential dividers 53, 54, 55 which are positioned over hub 60 and between spacers 61, 62, 63. A silicon lubricant 65 is added to the interior of the housing 64 and a closure member 70 is connected to the housing 64 by the use of cap screws 71.

In operation, the housing 64 is fixedly mounted on the rotating shaft 32 as described in association with the method of Figure 1. As an imbalance arises in member 33, the cylindrical weights 50, 51, 52 will freely move

within the grooves 43, 44, 45 until they assume a position wherein they counterbalance the imbalance occurring in the member 33. It has been found that it is preferable to give the sides of the cylindrical disks 50, 51, 52 a slight bow in order that the discs 50, 51, 52 contact the dividers 53, 54, 55 with a minimal surface area wherein they are not influenced by any possible suction which might otherwise occur between the dividers 53, 54, 55, the silicon lubricant 65 used and the discs 50, 51, 52 of the Figure 5 embodiment. It is preferable that the cylinders or discs 50, 51, 52 move as freely as possible within the grooves 43, 44, 45 between the dividers 53, 54, 55 as is likewise true for the weights and balls of the Figures 1 and 3 embodiments.

Yet a further embodiment of the invention is illustrated in Figures 6 and 7, Figure 6 illustrating four (4) grooves or races and Figure 7 illustrating only three (3) grooves or races. In this embodiment, the counterbalancing apparatus generally illustrated at 70 is symmetrical about both axes 71, 72 and is mounted to a shaft 32 similar to the Figure 1 embodiment.

In this embodiment, however, a central circumferential member 73 made from a solid piece of material is machined with a plurality of annular grooves generally illustrated at 74 on both faces. Balls (Figure 7) are mounted in the grooves 80, 81, 82, 83, the balls mounted in the outermost groove 80 being the largest and the balls in the innermost groove 83 being the smallest. After providing the silicon lubricant within each of the grooves 74, two end plates 81 are mounted to the central circumferential member 73 by the use of cap screws 82. The operation is similar to the operation of the Figure 3 embodiment; that is, when an imbalance occurs in member

33, the balls in each groove will assume a position wherein the imbalance is removed.

It is not again presently known why such is the case, but it has been found that seven (7) balls or weights in each groove or annular space of each of the embodiments appear to be an optimal number. It is, however, also believed that a greater or smaller number of balls or weights would usefully serve to remove various imbalances under various operating conditions.

A rule of thumb has arisen which has been helpful to the applicant in its current product development. It has been found that the quantity of the imbalance that may be potentially removed from an out of balance member by the counterbalancing apparatus is the sum of the weights in each of the grooves or races of the counterbalancing apparatus.

A further embodiment of the invention is illustrated in Figures 8A and 8B. In this embodiment, the counterbalancing apparatus 74 according to the invention is illustrated as being made from two sections 90, 91, which sections are mounted about shaft 32 by cap screws 92, 93 and which sections 90, 91 are freely removed from shaft 32 by removing the cap screws 92, 93. This embodiment is particularly useful where minimal modifications are desirably made to the rotating shaft 32 or to the out of balance member 33. Rather, the counterbalancing apparatus 74 is simply connected to the shaft 32 at a position where it is possible so to attach the counterbalancing apparatus 74 and the cap screws 92, 93 are tightened to firmly couple the apparatus 74 to the shaft 32.

Yet a further embodiment is illustrated in Figures 9 and 10. In this embodiment, it is contemplated that the counterbalancing apparatus 74 is mounted inside the outer circumference of a rotating shaft 32. As illustrated in Figure 9, the grooves or races 100, 101, 102 are machined directly into the solid material of shaft 32 and the balls 103, 104, 105 are positioned directly therein for free movement relative thereto. A cover 110 is connected to the shaft 32 and the balls 103, 104, 105 are thereby retained. In operation, as an out of balance condition occurs either in the out of balance member 33 (Figure 1) or in shaft 32 itself, the balls 103, 104, 105 will orient themselves in a configuration such as the configuration illustrated in Figure 10. In such positions, the shaft 32 and/or the unbalanced member 33 is balanced by the position of the balls 103, 104, 105 under dynamic operation conditions.

It has been found that under certain conditions and particularly at lower r.p.m.'s of the counterbalancing apparatus 10, the weights 21 (Figure 11) will tend to remain in a substantially stationary position in the groove 11 until the revolutions per minute of the counterbalancing apparatus increase to the point where the weight 21 is carried around the uppermost point of the inside diameter of the groove 11 or from one side of the radial 25 to the other or until the centrifugal force acting on the weights forces them outwardly until they are in an operating engagement with the outer surface of the groove 11 which will then exert a certain friction force that will tend to carry them around with the groove 11. After operating speeds occurs, the weights 21 will then quickly rearrange themselves with minimal movement so as to properly balance any unbalance condition. It has been found, for example, that at higher rotational speeds of the balancing device, the weights 21 within the grooves

will quickly rearrange themselves to set off any imbalance in the device. However, at low speeds, this not always the case and, accordingly, it is convenient to utilise means to move the weights with the groove or, at least, to provide a force on the movable weights which will tend to move the weight with the groove as it rotates about its axis.

Any delay in removing the imbalance is not advantageous since if a shaft, for example, being in balance and rotating, suddenly encounters an out-of-balance condition, it is conceivable that the weights 21 may not move quickly enough to remove the out-of-balance condition before damage results to the system.

The means used to improve the "quickness" with which the system responds to remove the out-of-balance condition can take several forms. It is, for example, contemplated that a substance could be added to the grooves 11 so that a force is imparted to the weights 21 which force will be such that the weights 21 will move from a stationary position as indicated to a position "over-the-top" of the member 10 and from one side of the radial 25 extending from the axis 26 of the member 10 to the opposite side. Alternatively, mechanical or electrical means could be used.

With reference to Figure 11, it is contemplated that the initial movement of the weights 21 within the groove 11 may occur by the addition of a substance to the grooves 11 that will initially give a degree of force to the weight so that the movement of the weights 21 is initiated by the substance. For example, such a substance could be a fluid of a consistency to impart the rotational movement to the weights, such as grease. An exhaustive list of all such substances is not immediately

contemplated but such a list might include virtually any substance to initiate movement of the weights 21. Even sand is contemplated as such a substance but, of course, sand may be inappropriate because of contamination and eventual binding of the weights 21 within the groove 11 which would affect normal operation where quickness of weight movement may not be necessary.

It is also contemplated that the initial weight movement could be initiated externally of the counterbalancing apparatus 10. For example, if the weights 21 were made of a magnetic material, an external probe (not illustrated) could apply a suitable magnetic field to the weights 21 which would allow the weights 21 to immediately commence movement in the event an unbalanced condition is encountered. This would be intended to reduce the rotation time of the weights 21 so that the unbalanced condition can be removed and would thereby reduce the chance of damage to the out-of-balance apparatus.

Reference is made to Figure 12 which illustrates the balancing device generally illustrated at 100. A liquid 101 is added to the balancing device 101 and takes a level 102 above the movable weight in the form of ball 103. A V-shaped groove 104 is formed in groove 110 in which ball 103 is intended to move. The V-shaped groove 104 has a plurality of passages 111 which extend from the groove 104 to a liquid reservoir (not illustrated).

In operation and when the balancing device 100 begins to rotate, the liquid 103 will tend to rotate with the groove 110 and, therefore, will exert a force on ball 103 which tend to rotate the ball 103 with the groove 110. As the speed of rotation of the balancing device increases, the centrifugal force on the liquid will

increase and, therefore, there will be a tendency for the liquid 101 to exit through passageway 111 and thereby to terminate any further influence over the movement of ball 103 which, by that time, will be rotating at the same speed as the balancing device 100. This is beneficial for the previously mentioned reasons, namely that if the balls 103 move quickly at speed, any imbalance arising will be quickly corrected.

A further embodiment of the invention is made with reference to Figure 13. The balancing device generally illustrated at 200 includes a movable weight in the form of a ball 201 and includes a pin 202 which is spring mounted within a radially inwardly extending opening 204. A compression spring 203 acts on the pin 202 to force it outwardly in the position indicated and thereby restrains movement of the ball 201 upon rotation of the balancing device.

As the balancing device 200 commences to rotate, the pin 202 will cause the ball 201 to rotate with the groove 205. The speed will increase and as it does so, the centrifugal force acting on the pin 202 will tend to move the pin 202 inwardly in opening 204 thus allowing the balls 201 to rotate freely in the groove 205 thereby to freely assume any position to connect an imbalance in the rotating machinery to which the balancing device 200 is attached.

Reference is now made to Figure 14 which diagrammatically illustrates two embodiments of the invention which may be used with a bearing 300 having standard balls 301 mounted so as to allow rotation of shaft 302 with reduced friction. However, it is desirable to remove imbalances in the shaft 302 and, to that end, a

balancing device 303 or a balancing device 304 may be added.

Balancing device 303 is connected so that it rotates with the shaft 302 and the movable weights in the form of balls 305 move about axis 306 of shaft 302 in a direction transverse to the direction of axis 306 and, in balancing device 304, the weights in the form of balls 310, 311, 312 rotate longitudinally or parallel to the axis 306 of the shaft 32.

The balls 305, 307, 308 are of different diameters and this applies likewise to the diameter of balls 310, 311, 312. Either configuration may be useful depending upon the geometrical considerations present in the system which is being used which includes shaft 302 and bearing 300.

Reference is now made to Figure 15A which illustrates the water containing cylinder or "tub" 400 of an ordinary washing machine. Two balancing devices 402, 403 are connected to the tub 400 to remove any imbalance upon operation although one, of course, may be sufficient to remove imbalances. The balancing devices 402, 403 may again take two different forms.

Referring initially to Figure 15B, the balancing device 402 may take the form of a plurality of grooves 403, 404 which extend circumferentially about axis 406 longitudinally or parallel to the axis 406. Movable weights in the form of balls 407, 408 are mounted in the grooves 404, 405 and serve to remove imbalances when the tub 400 is rotated.

Alternatively, the balancing device 402 may have grooves 409, 410 machined transverse to axis 406. The

balls 411, 412 are movable in their respective grooves 409, 410 and, again, remove imbalances when the tub 400 rotates about axis 406.

Yet a further embodiment of the invention is illustrated in Figure 16 in which the rear end of a vehicle 500 is diagrammatically shown. A gear box or differential 501 has two axles 502, 503 extending outwardly from the gearbox 501 and connect to rear wheels 504, 505 which, of course, rotate with axles 502, 503 when the vehicle is under operation.

An imbalance may arise in the system. For example, the tires 504, 505 may become out of balance for various reasons including the fact that flats form on the tires. This is particularly true in formula race cars where the speeds of the cars vary greatly throughout a circuit and the tires are subjected to highly variable forces.

To correct the imbalance, balancing devices 506, 507 may be added to axles 502, 503, although only one per axle may be required. These would function in the same way as has been discussed as the axles 502, 503 rotate both axially and about gearbox 501 as is illustrated. In the event the rotation about gearbox 501 is not severe, it may be convenient to mount the balancing devices 508, 509 on the axles 502, 503 as is shown in Figure 16.

Reference is now made to Figure 17 which illustrates a crankshaft 600 having a crankpin 605 to which is attached piston rod 601 which is connected to piston 602. Piston 602 may be used, for example, in a compressor. Two balancing devices 603, 604 are connected to crankshaft 600 as illustrated. The operation of each is similar to the operations described and they serve to

continuously remove imbalances in the system as previously set forth.

While it is presently anticipated that the counterbalancing apparatus according to the invention be made from a metallic material, it is also contemplated that other materials may well be appropriate such as composite material structures and plastic or the like, depending on the operating conditions under which the counterbalancing apparatus is intended to function.

While specific embodiments of the invention have been described, such embodiments should be considered as illustrative of the invention only and not as limiting its scope as defined in accordance with the accompanying claims.

WHAT IS CLAIMED IS:

1. A counterbalancing structural member rotatable about an axis, said member comprising first and second annular grooves concentric to said axis and extending around said axis, a first plurality of weights freely movable in said first annular groove, a second plurality of weights freely movable in said second annular groove, said first plurality of weights in said first annular groove being substantially the same weight and size, said second plurality of weights in said second annular groove being substantially the same weight and size, said weight and size of said second plurality of weights being different from said weight and size of said first plurality of weights.

2. A counterbalance structural member as in claim 1 wherein said first and second annular grooves are located on the outside circumference of said member, said grooves being longitudinally separated by a portion of said outside circumference.

3. A counterbalance structural member as in claim 2 wherein said weights are spherical.

4. A counterbalance structural member as in claim 2 wherein said weights are cylindrical and disc-like.

5. A counterbalance structural member as in claim 1 wherein said first groove is an outer groove located near the outside circumference of said member and said second groove is an inner groove concentric to and positioned inside said outer groove.

6. A counterbalance structural member as in claim 5 wherein said weights in said first outer groove are heavier than said weights in said second inner groove.

7. A counterbalance structural member as in claim 6 wherein said member comprises first and second substantially symmetrical halves and means to connect said halves, said halves being operably to be positioned about a rotating shaft.

8. A counterbalance structural member as in claim 5 wherein said first and second annular grooves are formed on one face of said member, said member further comprising a second face opposed to said first face, said second face having third and fourth annular grooves, a third plurality of weights freely movable in said third annular groove, a fourth plurality of weights freely movable in said fourth annular groove, said third plurality of weights in said third annular groove being substantially the same weight and size, said fourth plurality of weights in said fourth annular groove being substantially the same weight and size, said weight and size of said fourth plurality of weights being different from said weight and size of said third plurality of weights.

9. A counterbalance structure as in claim 8 wherein the weights in each of said grooves are spherical.

10. A counterbalance structure as in claim 9 wherein the number of said weights in each of said grooves numbers seven (7).

11. A counterbalance structure as in claim 5 wherein the number of said weights in each of said grooves numbers seven (7).

12. A method of dynamically balancing a rotating member comprising the steps of positioning a first plurality of weights having the same size and weight in a first annular groove in a rotating structure, positioning a second plurality of weights having the same size and weight and different from the size and weight of said first plurality of weights in a second annular groove in said rotating structure and rotating said structure while allowing free movement of said first and second plurality of weights in said first and second annular grooves.

13. A method of dynamically balancing a rotating member as in claim 12 wherein the outer inside circumference of said first and second annular grooves are identical.

14. A method of dynamically balancing a rotating member as in claim 12 wherein the first annular groove is coaxial with and located outside said second annular groove.

15. A method to counter an imbalance in a rotary member comprising the steps of positioning a counterbalance structure on the axis of said rotary member, positioning a first plurality of weights having the same weight and size in a first annular groove located coaxial with said axis and extending about the circumference of said structure, and allowing each of said first plurality of weights to freely move within said first annular groove, positioning a second plurality of weights having the same weight

and size in a second annular groove located coaxial with said axis and inside said first annular groove and allowing each of said second plurality of weights to freely move within said second annular groove, said second plurality of weights having a different weight and size from said first plurality of weights.

16. A method to counter an imbalance in a rotary member comprising the steps of positioning a first half of a structural member having first and second annular grooves with freely movable weights located in each of said annular grooves on a rotary member, positioning a second half of a structural member having third and fourth annular grooves symmetrical with said first and second annular grooves of said first half of said structural member on said rotary member, connecting said first and second halves, rotating said rotary member and allowing said freely movable weights to position themselves within said grooves so as to remove substantially all of said imbalance.

17. A counterbalancing apparatus comprising a shaft having an outer diameter, at least two grooves formed in said shaft, said grooves being coaxial with the axis of said shaft and formed one inside the other, the outside one of said grooves being inside the outer diameter of said shaft, freely movable weights positioned in each of said grooves and means to retain said weights in said grooves.

18. A counterbalancing apparatus as in claim 17 wherein said weights are spherical.

19. A counterbalancing apparatus as in claim 18 wherein the weight of each of said spherical weights in said

outside one of said grooves is identical and greater than the weight of each of said spherical weights in said inside one of said grooves.

20. A counterbalancing apparatus as in claim 19 wherein the size of said spherical weights in said outside one of said grooves is identical and greater than the size of said spherical weights in said inside one of said grooves.

21. A counterbalancing apparatus as in claim 19 wherein the size of said spherical weights in said inside one of said grooves is identical.

22. A counterbalancing structural member rotatable about an axis, at least one groove in said structural member being concentric with said axis, at least one weight movable in said groove, and means to retain said weight more stationary relative to said groove until said weight moves from one side of the vertical radial extending from said axis to the other side when said structural member is rotated about said axis.

23. A counterbalancing structural member as in claim 22, wherein said retaining means is a fluid.

24. A counterbalancing structural member as in claim 22, wherein said retaining means is grease.

25. A counterbalancing structural member as in claim 22, wherein said retaining means is an abrasive.

26. A counterbalancing structural member as in claim 25, wherein said retaining means is sand.

27. A counterbalancing structural member as in claim 22, wherein said retaining means is located externally of said structural member.

28. A counterbalancing structural member as in claim 27, wherein said retaining means is a magnetic probe.

29. A washing machine having a water retaining cylinder rotatable about an axis, at least one cylindrical balancing device having an axis and being mounted concentric to said axis, said balancing device having at least two passageways, movable weights within each of said passageways, said movable weights in said first passageway being all substantially the same size, said movable weights in said second passageway being all substantially the same size, the movable weights in said second passageway being a different size from the movable weights in said first passageway.

30. A washing machine having a water retaining cylinder being rotatable about an axis, at least one cylindrical balancing device operably connected to said cylinder and having an axis, said balancing device being mounted concentric to said axis, said balancing device including at least one passageway to hold movable weights, said weights being rotatable with said balancing device and being movable relative to said passageway, all of said weights in said passageway being substantially the same size.

31. A balancing device being operably connected to a rotating member and being concentric with the axis of said rotating member, said balancing device having at least one passageway extending circumferentially about the axis of said balancing device, a plurality

of weights within said passageway and being movable relative to said passageway, means to maintain said weights substantially stationary relative to said passageway until a predetermined rotational speed of said balancing device is reached.

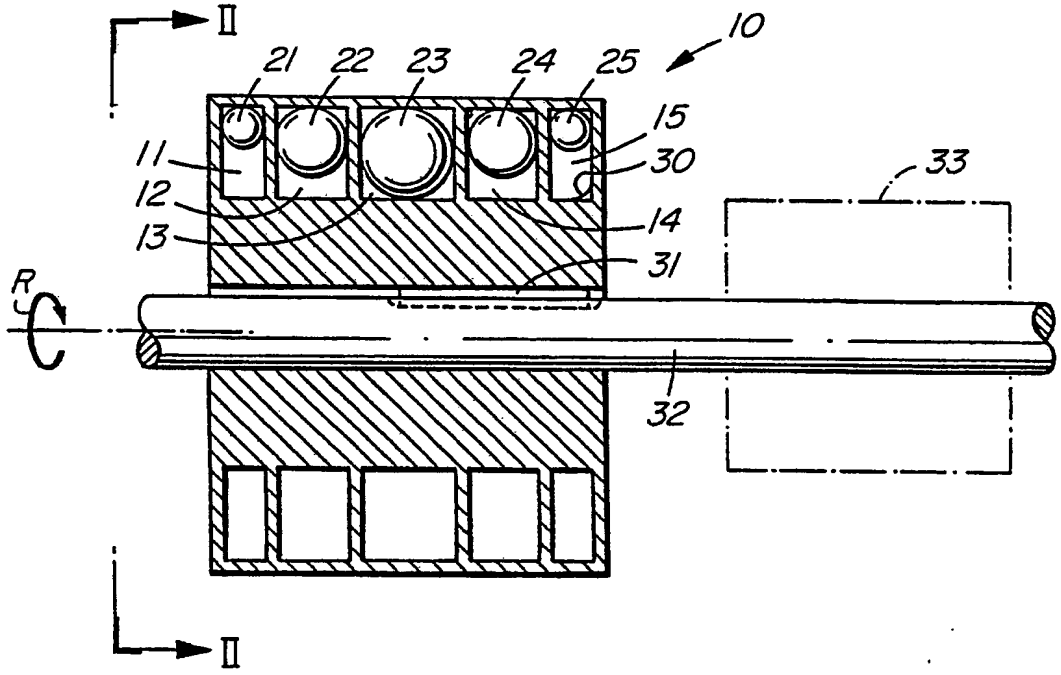
32. A balancing device as in claim 31 wherein said weight maintaining means is a fluid added to said balancing device.

33. A balancing device as in claim 31 wherein said weight maintaining means is a groove with a fluid disposal passageway connected to said groove.

34. A balancing device as in claim 31 wherein said weight retaining means is a spring mounted pin operable to retract from said outwardly located position under rotation of said balancing device.

35. An axle for a vehicle or the like, said axle being rotatable about an axis, a balancing device being operably connected to said axle and having a passageway extending about the axis of said axle, a plurality of weights in said passageway and being movable within said passageway, all of said weights in said passageway being substantially the same size.

36. A compressor having at least one piston operably connected to a rotatable crankshaft, a balancing device being operably connected to said crankshaft and having a circumferential passageway extending about the axis of said crankshaft, said passageway having a plurality of weights movable relative to said passageway, each of said plurality of weights being substantially the same size.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II

FIG. 1

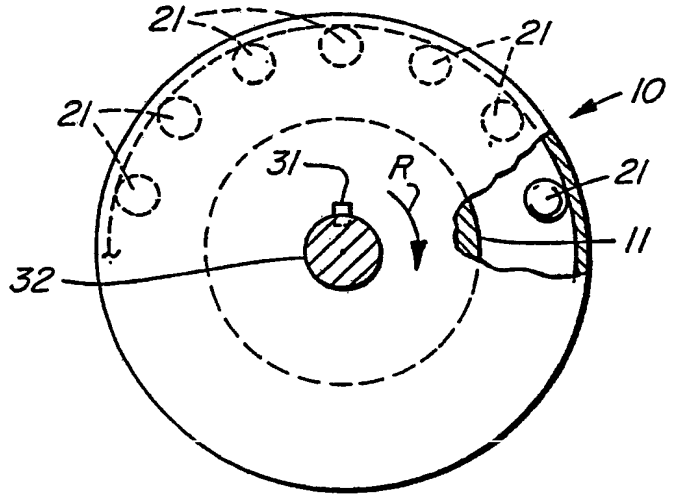
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FIG. 2

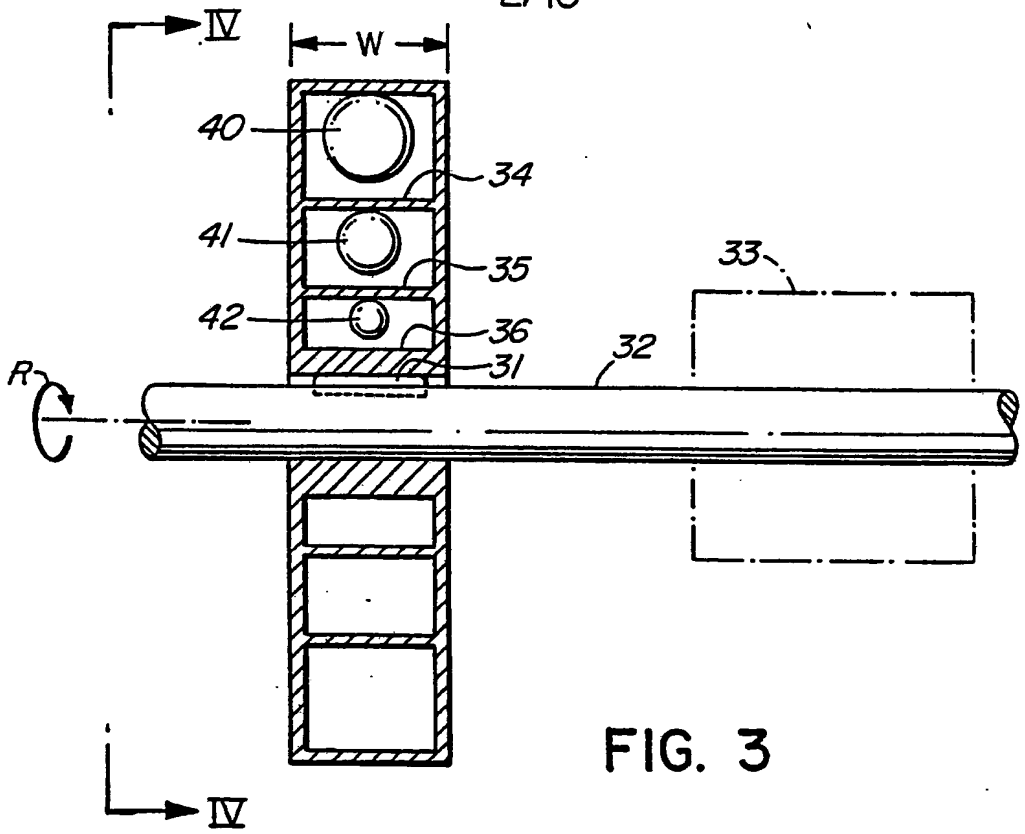

FIG. 3

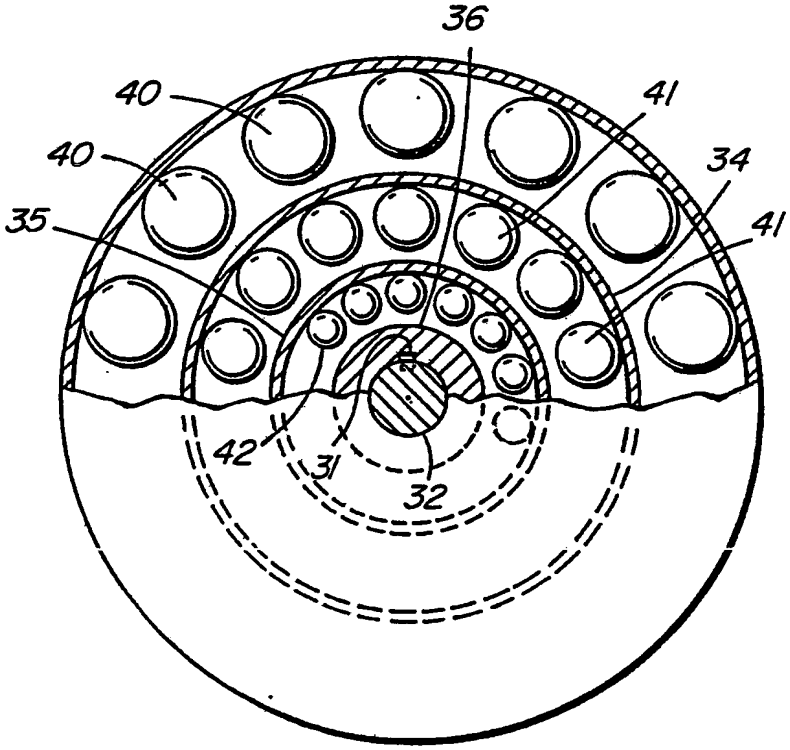

FIG. 4

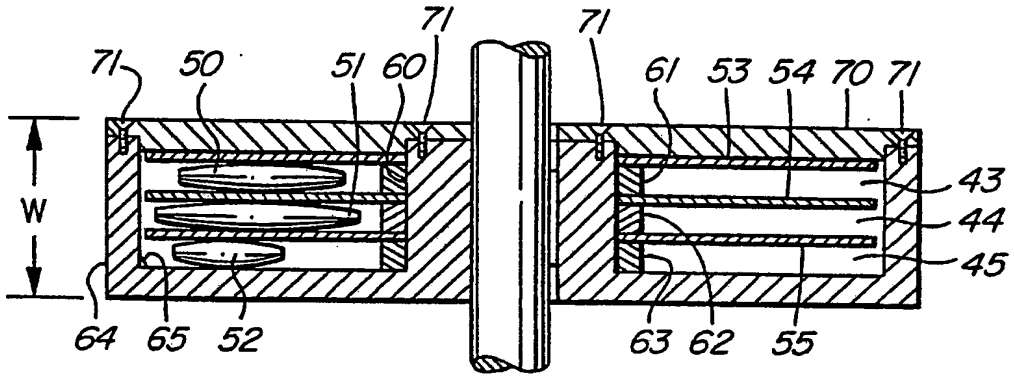
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FIG. 5

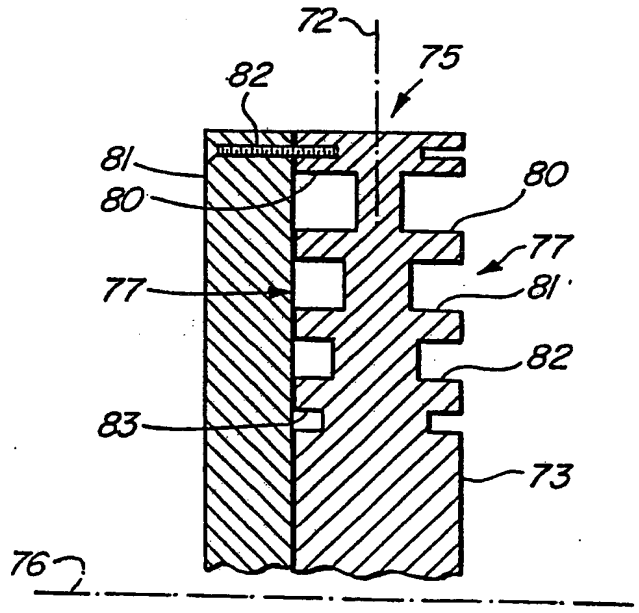
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FIG. 6

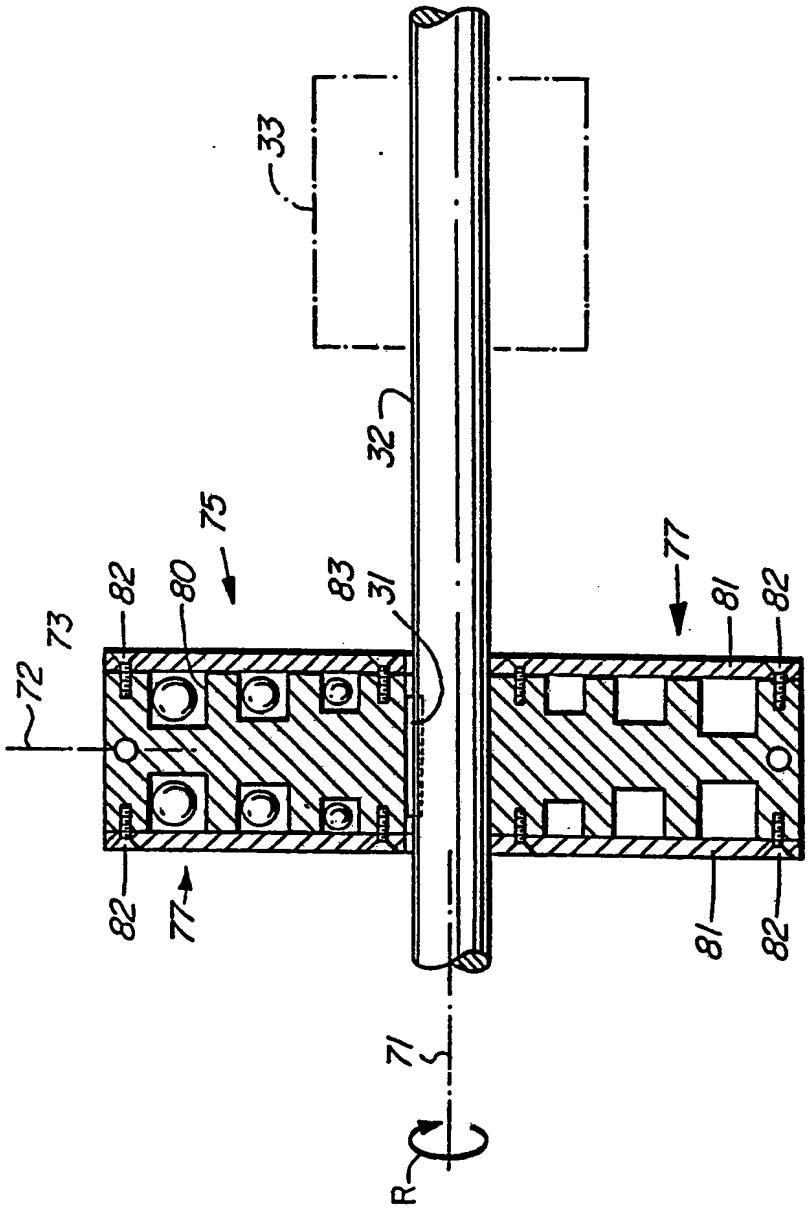

FIG. 7

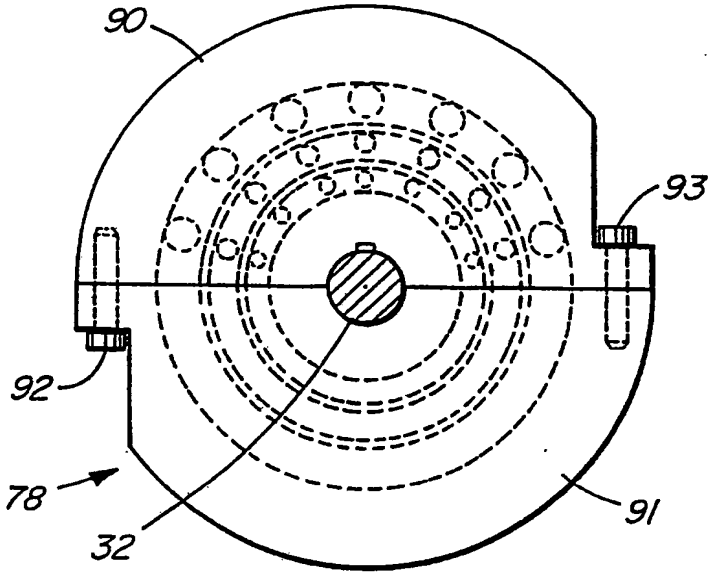

FIG. 8A

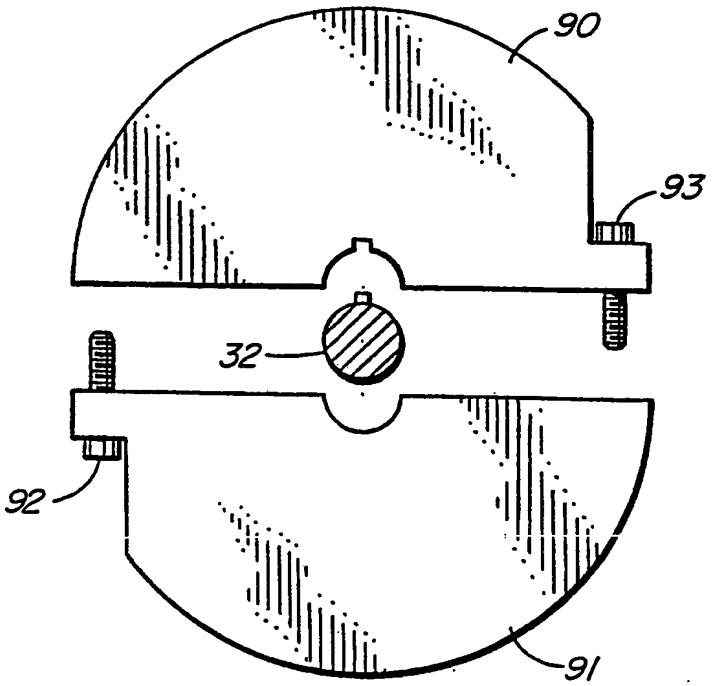

FIG. 8B

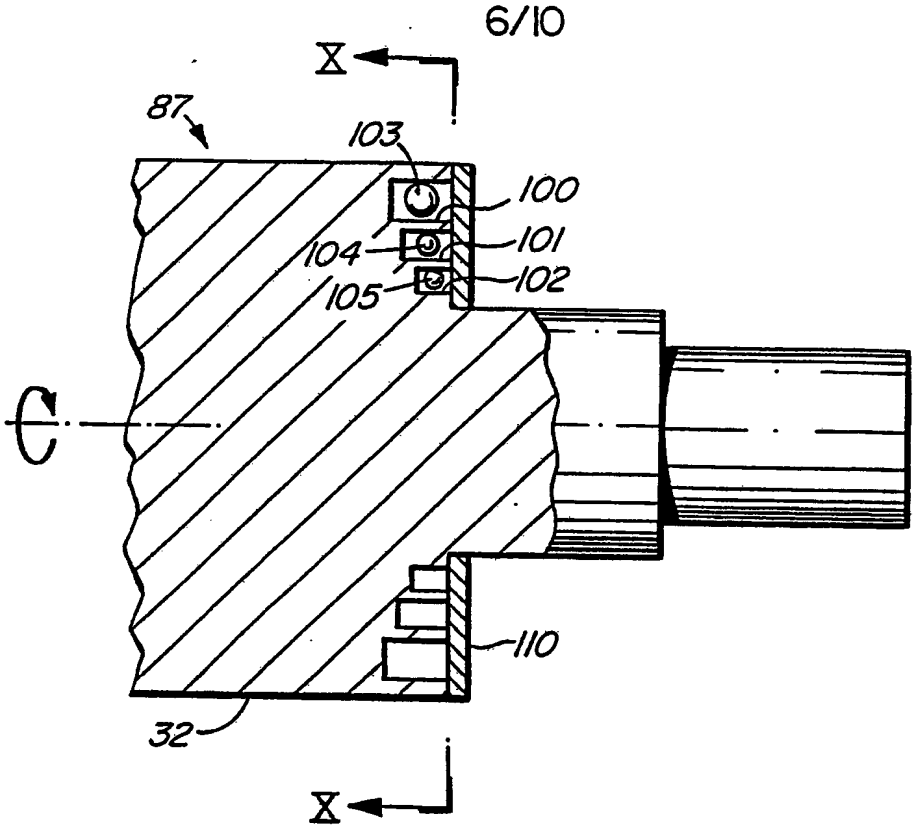

FIG. 9

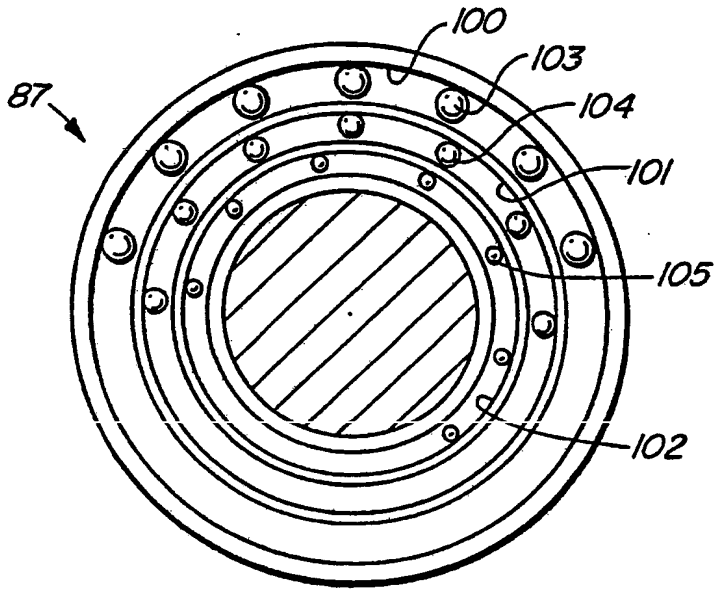

FIG. 10

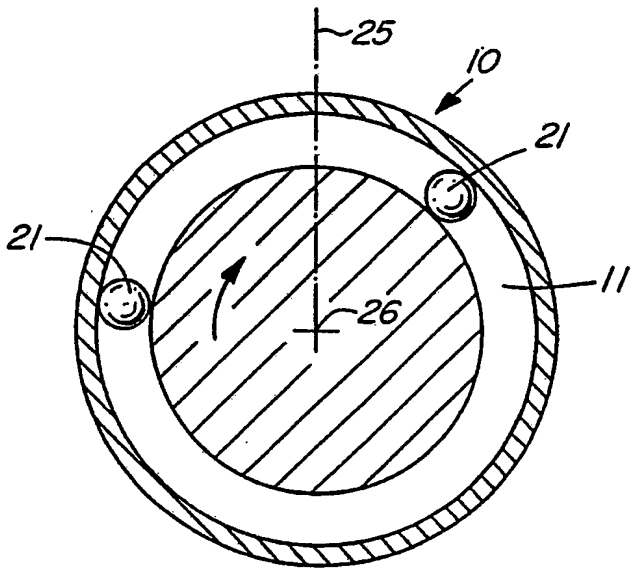

FIG. 11

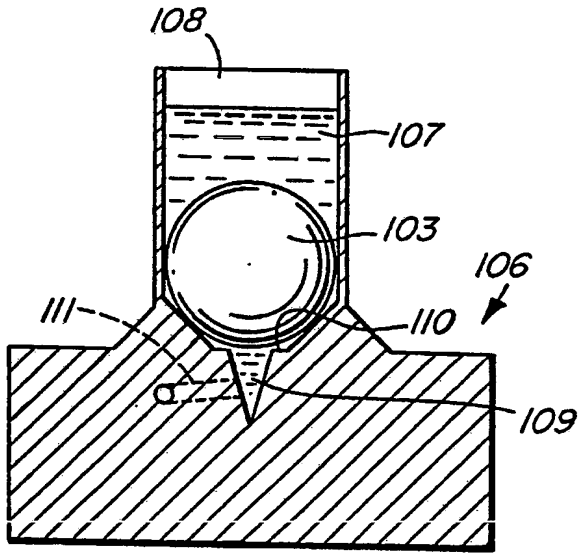

FIG. 12

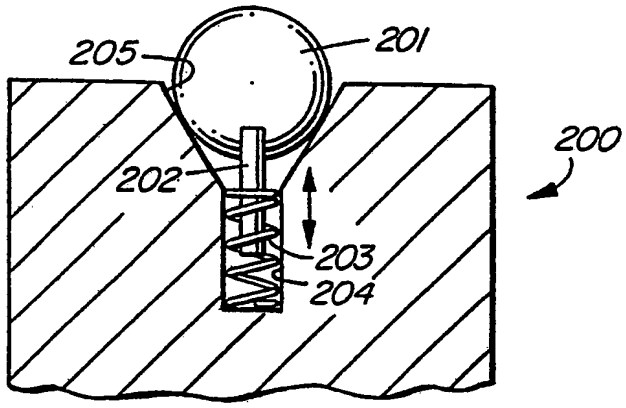
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FIG. 13

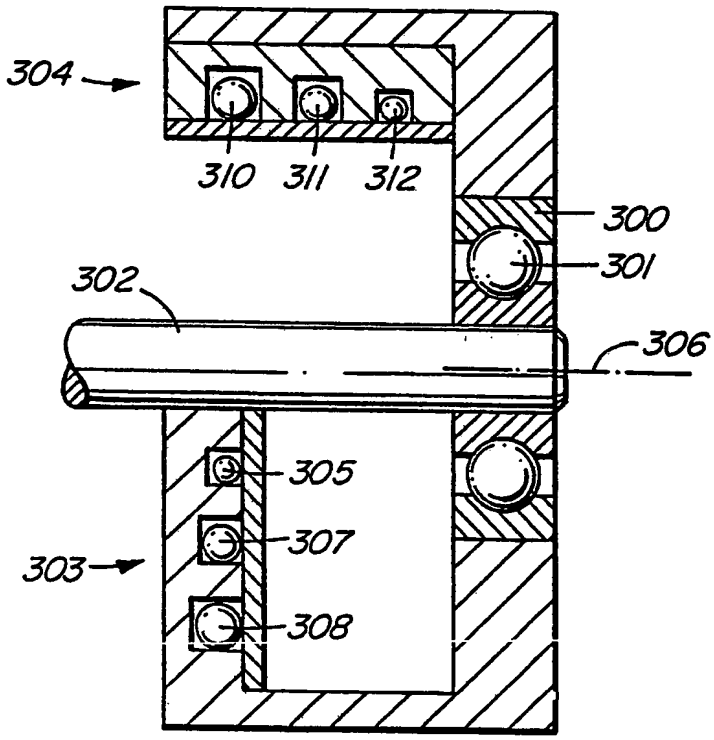
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FIG. 14

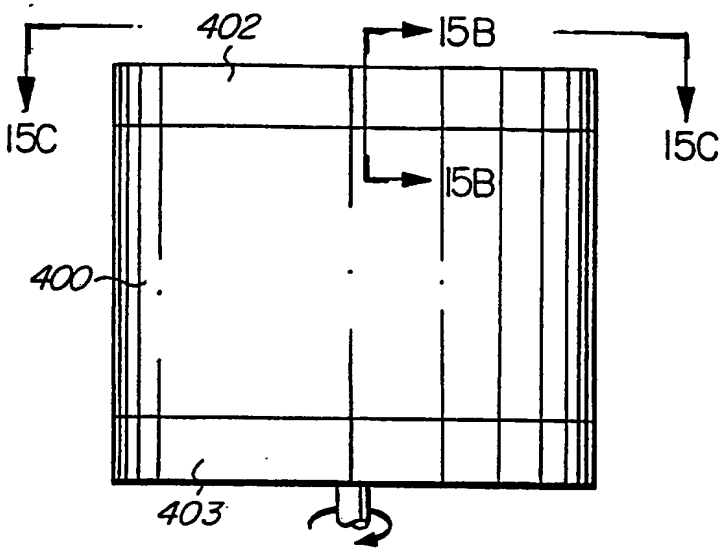

FIG. 15A

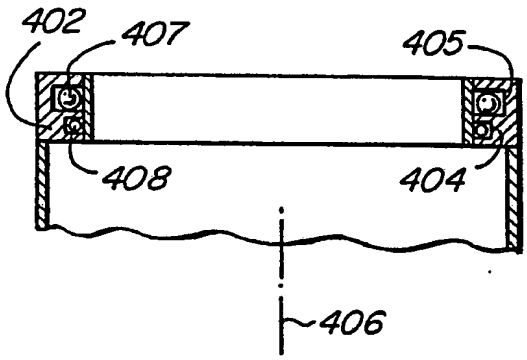

FIG. 15B

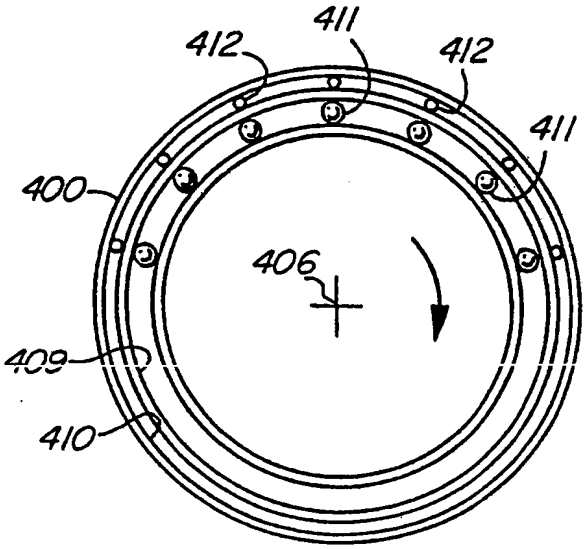

FIG. 15C

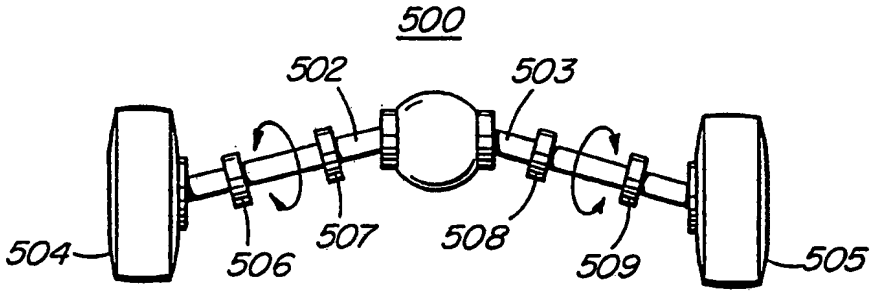

FIG. 16

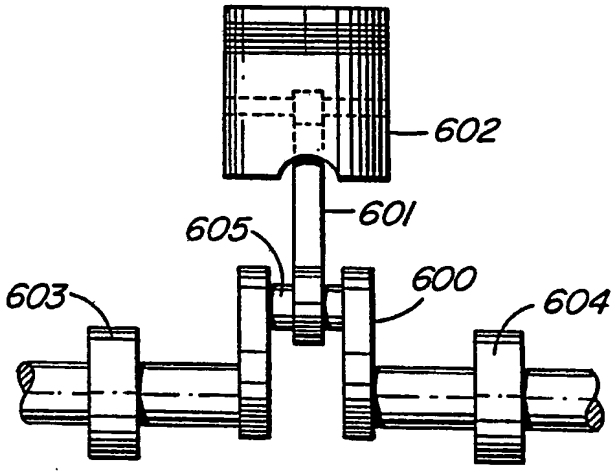

FIG. 17

INTERNATIONAL SEARCH REPORT

International Application No PCT/CA 93/00218

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)[6]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int.Cl. 5 F16F15/32

II. FIELDS SEARCHED

Minimum Documentation Searched[7]

Classification System	Classification Symbols
Int.Cl. 5	F16F

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched[8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT[9]

Category °	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No.[13]
Y	US,A,4 905 776 (P.A.BEYNET ET AL) 6 March 1990 cited in the application see claim 1; figure 3	1-4,12, 13,15, 22,23
A	---	29
Y	US,A,2 331 756 (R.A.ZOBEL) 12 October 1943 see page 1, column 1, line 39 - line 43 see page 1, column 2, line 50 - page 2, column 1, line 5	1-4,12, 13,15, 22,23
A	---	27
A	US,A,3 953 074 (WOODROW WILSON COX) 27 April 1976 see claim 1; figures	1-3,12, 13,15, 22,23,29

	-/--	

° Special categories of cited documents : [10]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
17 AUGUST 1993	
International Searching Authority	**Signature of Authorized Officer**
EUROPEAN PATENT OFFICE	PEMBERTON P.

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category °	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
A	PATENT ABSTRACTS OF JAPAN vol. 10, no. 73 (M-463)(2130) 22 March 1986 & JP,A,60 215 137 (TOMIO INO) 28 October 1985 see abstract	5,14,17, 27
A	GB,A,832 048 (G.SCHAFER ET AL) 6 April 1960 see claim 6	28
X	US,A,3 799 619 (J.A.LABARBER) 26 March 1974 see column 1, line 5 - line 11; claim 1	31
A		29,30, 35,36
A	US,A,3 433 534 (G.E.MERCER) 18 March 1969 see column 8, line 56 - line 58	31
X	NL,C,97 059 (FRAME SA) 15 February 1961 see figures	30
A		29
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